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Patricia K. Kuhl

Department of Speech and Hearing Sciences and Virginia Merrill Bloedel Hearing Research Center, University of Washington, WJ-10, Seattle, Washington 98195

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A new series of studies on adults' and infants' perception of phonetic "prototypes," exceptionally good instances of phonetic categories, show that prototypes play a unique role in speech perception. Phonetic category prototypes function like "perceptual magnets" for other stimuli in the category. They attract nearby members of the category, rendering them more perceptually similar to the category prototype than would be expected on the basis of physical distance alone. Nonprototype stimuli from the category do not function in this way. Moreover, by 6 months of age, infants tested in the United States and Sweden show that the perceptual magnet effect is language-specific. Infants from the two countries exhibit the magnet effect only for the phonetic prototypes of their own native language. Thus, exposure to a specific language alters infants' perception of speech by 6 months of age. These results offer an explanation for the findings of a variety of studies on cross-language speech perception in infants and adults, have implications for second-language learning, and are consistent with data on the representation of cognitive categories outside the domain of speech. The results support a new model which describes how innate factors and experience with a specific language interact in the development of speech perception.

INTRODUCTION

We recently began a series of studies on adults and infants that focus on perceivers' definition of the centers of phonetic categories, the ideal members or "prototypes" of phonetic categories [1, 2, 3]. Much of the work in speech perception has focused on stimuli containing a minimum number of acoustic cues. While these stimuli are sufficient to allow discrimination, they do not contain all of the cues that are normally present in speech, and therefore do not show how the many acoustic cues contained in speech are combined during speech perception. My focus on the prototypes of speech categories is based on the assumption that prototypes exemplify an optimum combination of the many acoustic events that contribute to category identification, and the belief that prototypes tap listeners' mental representations or internal standards for speech categories [4]. Prototypes thus provide a method for examining the mental representation of phonetic categories.

Category prototypes have been shown to play a special role in the perception and categorization of objects and events outside the domain of speech [5, 6]. In the literature on speech perception, there is support for the idea that certain stimuli have privileged status [7, 8]. The purpose of the studies described here was to determine whether listeners could identify good instances (prototypes) of phonetic categories, and to examine the role that phonetic prototypes play in perception. The goals of this paper are two-fold: (i) to describe the set of experiments on phonetic prototypes conducted with adults, infants, and animals, and (ii) to develop a theory of the representation of phonetic categories with particular emphasis on its development in infants.

Identifying phonetic prototypes

The approach adopted in these experiments was to ask adult listeners to rate the category goodness of individual exemplars from a phonetic category in their native language. Stimuli that were rated as the best exemplars, or prototypes, were then examined further in tests that compared the perception of prototypes to the perception of nonprototypes from the same category. We hoped to determine whether prototypes played a special role in the organization and representation of phonetic categories.

Our initial tests were conducted using vowel sounds [1, 2], and we have now undertaken a matching set of studies involving consonants [9]. To conduct the vowel tests, many different instances of the vowel /i/ were computer synthesized, creating exemplars that covered the entire range of formant values typically produced by adult speakers. Adult native speakers judged the category goodness of each of the vowels using a scale from 1 to 7. A "7" indicated a particularly good exemplar, a perfect /i/. A "1" indicated an /i/, but a very poor one. The findings showed that adults' ratings were very consistent [1, 2]. There was a particular location in the /i/ vowel space that produced better ratings. As one moved away from that "hotspot," the ratings became consistently worse. These findings showed that adults did not perceive all members of a vowel category as equivalent. Some instances were perceived as better than others. Given that certain instances appeared to have special status, we were interested in whether these stimuli were special from a perceptual standpoint.

How phonetic prototypes function in perception

Two /i/ vowels were selected from the set that were rated by adults. One was the vowel exemplar given the highest average category goodness rating, a 6.7. It was designated the prototype (P) /i/. The second one was an /i/ that had been given a relatively poor average rating, a 2.0. It was designated the nonprototype (NP) /i/. Both the prototype /i/ and the nonprototype /i/ were always rated as /i/ vowels by listeners. The poor /i/ was simply judged to be produced less well. Listeners gave very consistent ratings of the vowels and showed striking agreement on the particular vowels that were perceived as best instances.

We computer synthesized 32 variants of P and of NP by manipulating the first and second formants of the two vowels (the third, fourth, and fifth formants were held constant). The 32 variants formed four rings around each of the two vowels (Fig. 1). Each ring was a controlled distance (measured in mels) from the center stimulus, either 30, 60, 90, or 120 mels from the center vowel.

The purpose of scaling the stimuli in mels was to equate distance between the 32 variants and the center vowel (P or NP). Using the mel-scaled stimuli, the variants on each of the four rings surrounding the P and the NP vowels (rings 1-4) were equally distant from their respective center vowel.

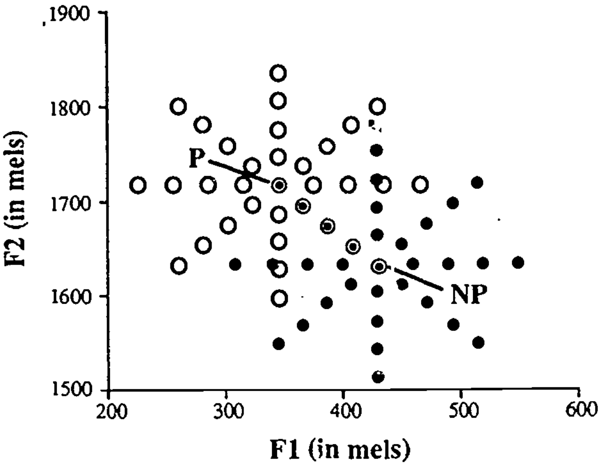

Figure 1. The prototype /i/ (P) and its 32 variants (open circles) and the nonprototype /i/ (NP) and its 32 variants (closed circles). The variants on the four rings are scaled in mels to equate for distance.

Each of the stimuli surrounding the P and the NP was rated for category goodness by adult native speakers using the 7-point rating scale. The results revealed that the hotspot for /i/ was fairly large, and that the ratings systematically and symmetrically declined as stimuli moved further away from that particular area (Fig. 2).

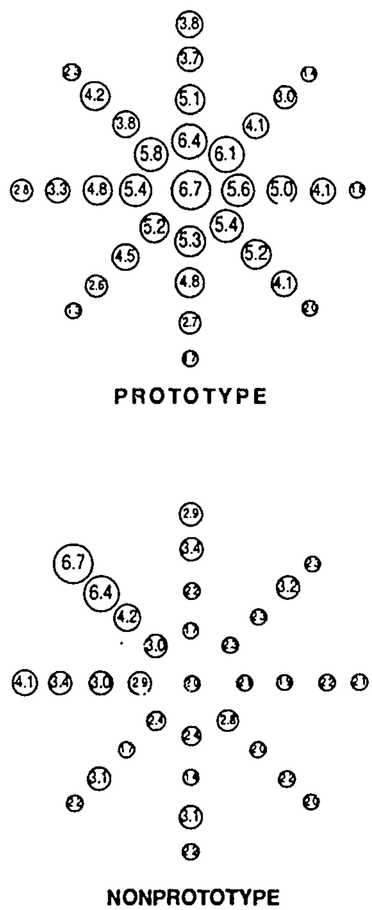

Figure 2. Category goodness ratings for the P /i/, the NP /i/, and the 32 variants surrounding each of the two vowels. The size of the circles correlates with the degree of goodness, with larger circles indicating better exemplars.

The two /i/ vowels and their variants were used to test the hypothesis that category goodness (typicality) has an effect on speech perception [2]. A discrimination test was used to test the degree of perceptual similarity between each vowel (P and NP) and its variants. Adults, 6-month-old infants, and rhesus macaques were tested in a discrimination task that was virtually identical for the three groups of subjects. All three groups were tested in two conditions. In one condition subjects judged the P against its variants, while in a second condition subjects judged the NP against its variants [2]. Each of the 32 stimuli surrounding the P or the NP was tested to examine whether it was perceived as the same or different from the P or the NP. The question was: Is the prototype perceived as more similar to its variants than is the case for the nonprototype?

<u>Results of tests on phonetic prototypes</u>

Human adults and infants showed the same pattern of results [2], that shown in Figure 3. The plot shows the percentage of variants on the four rings that were equated to the P or NP. As shown, the prototype produced a stronger magnet effect (more variants equated to the target). Thus, the prototype is perceived as more similar to its surrounding variants than is the case for the nonprototype. Variants have to be further away from the prototype than from the nonprototype in order to be discriminable from it, even though distance is controlled in the two sets of stimuli.

The results suggest that the prototype perceptually assimilates surrounding stimuli to a greater extent than is the case for the nonprototype. I have described the prototype as functioning like a perceptual magnet [2]. The prototype appears to draw other stimuli towards it, effectively reducing the perceptual distance between the prototype and surrounding stimuli.

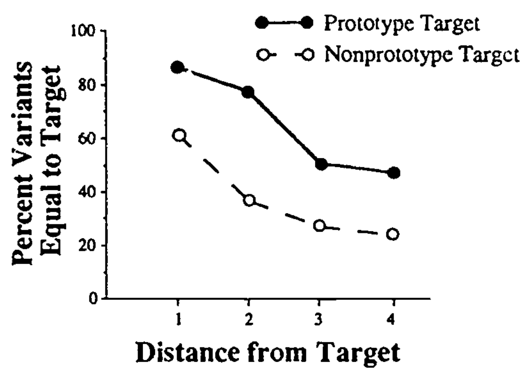

Figure 3. Results of a test of speech prototypes in infants. The prototype is equated to a greater percentage of variants, thus exhibiting a stronger magnet effect.

Monkeys demonstrated a strikingly different pattern of response. They exhibited no magnet effect [2]. Monkeys treated the variants surrounding the prototype and the nonprototype in exactly the same way. In both cases, variants were discriminated from the target at a particular distance from the target. These results are interesting because they reveal a dissociation between humans and monkeys in a test of phonetic perception. Previous tests in our lab on categorical perception revealed similarities in infants' and animals' responses to speech [10]. This suggests that the perceptual magnet effect differs in significant ways from the phenomenon of categorical perception [11].

LINGUISTIC EXPERIENCE AND THE MAGNET EFFECT: A CROSS-LANGUAGE STUDY

The existence of the magnet effect in 6-month-old infants raises interesting questions: What makes a particular vowel a prototype? And regarding development, how might the prototype's magnet effect come about in the baby?

The developmental question can be answered in two different ways, and each makes a prediction about the nature of the magnet effect. The first answer regarding development is that phonetic prototypes are part of infants' biological endowment for language. An alternative is that prototypes depend on linguistic input. By this account, infants' speech perception mechanisms begin at an early age to reflect the properties of the language spoken in their culture. This view takes the spoken language of the parents, which is still meaningless to the infant, as input that alters their perceptual space.

The two models make different predictions about infants' perception of vowels from a foreign language. The first hypothesis — that vowel prototypes are innately "fixed" — predicts that the prototype's magnet effect would exist for vowels that the infant has never heard. The second hypothesis predicts that the magnet effect would result only when vowels in the infant's own language were tested.

An international research team examined the two hypotheses in a cross-language test. Infants from the United States and Sweden were tested on two vowel prototypes, the American English vowel /i/ used in our previous tests and the Swedish vowel /y/ [3]. The Swedish /y/ prototype was synthesized and then modified to create 32 additional variants in the same way as previously described [3].

In both countries, tests on adult native speakers were conducted to assess the status of the foreign vowel. Adult native speakers of American English and Swedish were asked three questions about the /i/ and the /y/ prototypes: (i) whether it was a sound used in their native language, (ii) the category it belonged to, and (iii) its representativeness as a member of that category using our 7-point scale.

American listeners unanimously judged the American /i/ prototype as a native-language vowel, giving it a high rating as a member of the English /i/ category. They unanimously rated the Swedish /y/ prototype as not in their language. Swedish adults unanimously judged the /y/ prototype as a Swedish vowel, giving it a high rating as a member of the category /y/. Swedish adults rated the American English /i/ prototype as present in the language but rated it as a poor exemplar. The American English /i/ was most often considered a member of the Swedish /e/ category and was given an average rating of 2.6 as a member of that category.

Careful controls were adopted for the cross-language infant test. We moved the entire laboratory (computer, loudspeaker, cables, reinforcers, everything used to conduct the experiment), and three trained experimenters, from Seattle to Stockholm. Except for the critical variable, the language experience of the 6-month-old infants who were tested, the methods and procedures used to conduct the study in the two countries were identical. The question was: Would the magnet effect be exhibited universally for both prototypes by infants, or would the 6-month-olds from the two countries show the magnet effect only for native-language prototypes?

Infants from both countries showed a significantly stronger magnet effect for their native-language prototype (Fig. 4), confirming the hypothesis that linguistic experience in the first half-year of life alters phonetic perception. American infants perceived the American English /i/ prototype as identical to its variants on 66.9% of all trials; in contrast, they perceived the Swedish /y/ prototype as identical to its variants on only 50.6% of the trials. Swedish infants perceived the Swedish /y/ prototype as identical to its variants on 66.2% of all trials; in contrast, they treated the American English /i/ prototype as identical to its variants on only 55.9% of the trials. Infants' responses were analyzed using a two-way analysis of variance to assess the effects of language environment (American English versus Swedish) and the vowel tested (American English /i/ versus Swedish /y/). The interaction between the two factors was highly significant ($p < .0001$); neither of the main effects was significant (language environment, $p > .40$; vowel, $p > .30$).

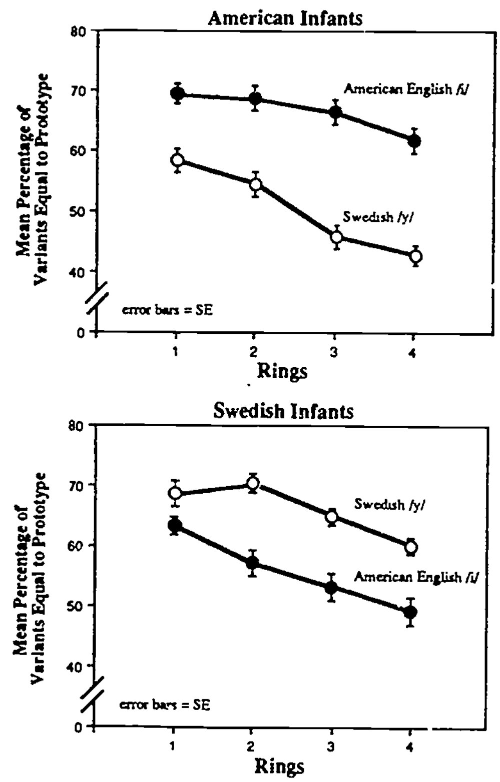

Figure 4. Results of the cross-language experiment on 6-month-old American (A) and Swedish (B) infants tested on two vowel prototypes, American English /i/ and Swedish /y/. The mean percentage of variants equated to the prototype on each of the four rings is plotted. Infants from both countries produced a stronger magnet effect for their native-language vowel prototype.

A THEORY OF PERCEPTUAL MAGNETS

Effects on cross-language speech perception

The onset of language-specific speech perception

The results show that by 6 months of age, infants' perception of speech has been altered by exposure to the ambient language. This is the earliest age at which linguistic experience has been shown to alter phonetic perception Previous studies by Werker suggested that the effects of linguistic experience on phonetic perception occur between

10 and 12 months of age [12], coinciding with the age at which children begin to acquire word meanings. It was thus suggested that the change from a language-universal pattern of phonetic perception to one that is language-specific might be brought about by a milestone in the child's linguistic development, namely, the child's understanding that phonetic units are used contrastively to specify different word meanings [13]. The present results suggest instead that the initial appearance of a language-specific pattern of phonetic perception does not depend on the emergence of contrastive phonology and an understanding of word-meaning. Rather, language-specific categories emerge as a result of exposure to the ambient language. Language-specific phonetic perception thus precedes word acquisition.

Native-language magnets and the perception of foreign language sounds

The magnet effect may help account for the results of studies on the perception of sounds from a foreign language. These studies suggest that phonetic units from a foreign language that are similar to a category in the subject's own native language are particularly difficult to perceive as different from the native-language sound; sounds that not similar to a native-language category are relatively easy to discriminate [14]. A classic example of a difficult foreign-language contrast is the case of /r-l/ discrimination by native speakers of Japanese [15]. The segments /r/ and /l/ are not phonemically contrastive in Japanese and native speakers have difficulty with the contrast even after considerable training [16]. I would suggest that this is due to the fact that the prototype of the Japanese category is similar to both /r/ and /l/ and that its magnet effect makes the two sounds difficult for native-speaking Japanese people to discriminate.

In a similar vein, Werker's developmental results show that infants tested at 10-to-12 months of age fail to detect differences between two foreign-language sounds that they could discriminate earlier in life [12]. The theoretical account developed here predicts that the cause of this failure to discriminate a foreign-language contrast is the development of the magnet effect for native-language phonetic categories. The developing magnet pulls sounds that were once discriminable towards a single magnet, making them no longer discriminable. I would predict, therefore, that native-language magnet effects will precede infants' failure to discriminate foreign-language contrasts. Preliminary data by Werker and Polka [17] support this hypothesis.

Implications for second-language learning

Studies on second-language learning suggest that the acquisition of a new language by adults poses difficulty at the level of phonology [18]. In particular, it has been suggested that the native-language categories of the listener somehow interfere with the ability to perceive the phonetic distinctions in the new language. The theory I am putting forward argues that the magnet effect contributes to this difficulty. As suggested above, native-language magnets attract similar sounds, and this makes certain foreign-language distinctions difficult to perceive, such as the segments /r/ and /l/ for native speakers of Japanese. The prediction that stems from the theory is that the difficulty posed by a given foreign-language unit will depend on its proximity to a native-language magnet. The nearer it is to a magnet the more it will be assimilated to the native-language category, making it indistinguishable from the native-language sound. Phonologists interested in second-language learning have developed an analogy that is consistent with the hypothesized magnet effect. The phonetic categories of ones' native language have been described as forming a "sieve" through which the phonetic units of the newly acquired language must pass [19]. The idea developed here, that native-language prototypes act like magnets which filter the new language's phonetic units, is consistent with this notion.

Second-language learning also raises a developmental issue, that of bilingual exposure to language early in life. We have yet to conduct experiments on infants reared in a bilingual home in which the infant is regularly exposed to two different languages. Our interest would be in tracking the development of the magnet effect in infants reared in bilingual homes using as test stimuli the sounds of both languages. My hypothesis would be that infants would show magnet effects for the sounds of both languages.

Magnet effects and speech representation

Development of a speech representational system

The findings show that by 6 months of age, infants' perception of the sounds of their native language differs from their perception of the sounds of a foreign language. Native-language prototypes exhibit the magnet effect while foreign sounds are treated as nonprototypes in the native language. This result allows the inference that infants have had sufficient listening experience with the ambient language to form rudimentary memory representations of the sounds in their native language.

The exact form that these representations take cannot be specified at this point. One possibility is that speech representations take the form of a single abstract stimulus that summarizes the experienced instances, such as an average (as assumed by traditional prototype models). Alternatively, speech representations could consist of a compilation of actual instances that have been experienced by listeners (as assumed by exemplar-based models) [20].

Studies on infants' perception of facial stimuli and dot patterns suggest that infants construct an average of the experienced stimuli after exposure to a set of exemplars [21, 22]. In one study infants were exposed to facial stimuli whose features, such as the overall length and width of the face and the nose, the distance between the eyes, and the squareness of the jaw, were systematically altered [21]. Infants saw a number of different faces, but were not exposed to the face that constituted the average of all the experienced faces. Nonetheless, infants subsequently treated the average face, a face that they had not seen during the experiment, as more familiar than a novel exemplar that was not the average. This result suggests that infants summarized the faces that they were exposed to in the form of an average of all the faces they experienced during the test. The data demonstrate that infants are capable of holding in memory an abstract summary of a series of complex visual stimuli.

Categorization studies outside the domain of speech show that typicality effects can be explained by both prototype models and by exemplar-based models. At the present time we do not take a position on which model offers the best description of the magnet effect. Mathematical models of attention [23] and memory [24] may help distinguish the two alternatives.

The unit of analysis question

The finding that phonetic units show a magnet effect raises questions about the unit of analysis in speech perception. The results suggest that the representation of speech information in infants does not consist of unanalyzable "wholes" constituted as syllables or words. Magnet effects for segmental categories indicate that speech representations must be comprised of units that are sufficiently fine-grained to allow such an effect to occur at the level of the segment.

Magnet effects are not likely to be limited to segment-length stimuli. As reviewed below, there are data demonstrating that infants in the first year are acquiring information about regularities in the prosodic structure of their native language. It would be interesting to explore the magnet effect using prototype stimuli fashioned to exemplify the stress and intonation patterns that typify those in the infant's native language. Magnet effects for multisyllabic prototypes typifying the prosodic structure of the infants' native language would suggest that the magnet effect is a general property of learned prototypes.

Are speech representations auditory, articulatory, or both?

The studies described here treat speech as an auditory event perceived through a single modality. Studies in my own lab and others show, however, that speech is perceived as a bimodal event wherein both the visual and the auditory concomitants of articulation play a role in determining perception. The data cannot be reviewed here in detail, but the auditory-visual effects observed in adults [25], as well as data showing that by 18 weeks of life infants recognize auditory-visual correspondences for speech [26], attest to the potency of visual information in speech perception and suggest that the cross-modal perception of speech is a fundamental ability that is present very early in life. Taken together, these data suggest that the speech representational system is polymodal in nature starting from infancy [27].

Recent collaborative work between my laboratory and Yoh'ichi Tohkura's group in Japan on the auditory-visual perception of speech suggests that the potency of visual information may vary across languages. Recent studies done in Japan suggest that Japanese subjects may be less likely than American subjects to be influenced by visual speech information when viewing a native-language speaker [28]. If these results are verified in our current cross-language studies, this will be an important indicant of the role of linguistic experience in the development of polymodal speech representations.

A THEORY OF DEVELOPMENT

The studies described here illustrate that the prototypes of speech categories play a unique role in speech perception. Phonetic prototypes function in a particular way. Stimuli in the category appear to be drawn towards the prototype. This is why I coined the term *perceptual magnet effect* to describe the prototype's effect on surrounding stimuli [2]. The results of our studies also reveal that the magnet effect depends on linguistic experience. Exposure to a specific language results in the perception of fewer differences among stimuli in the region of the prototype. Language experience has somehow warped the psychological space underlying the perception of the acoustic events underlying phonetic distinctions.

Moreover, the magnet effect is sensitive to linguistic experience at a very early age [3]. By the time infants reach the age of 6 months the magnet effect is language specific. At this age, infants only demonstrate the effect for native-language phonetic categories. Apparently, infants' perceptual systems are altered by exposure to language in the first half-year of life. These findings underscore the exquisite readiness of the infant to respond to linguistic input.

The role of language input

Results showing that language alters perception in the first 6 months of life has increased our interest in language input to the child. Studies of "motherese" have shown that language that is directed towards infants and children is acoustically quite distinct from that directed towards adults [29]. Its prosodic characteristics have been well described: Motherese is characterized by a higher overall pitch, exaggerated pitch contours, and a slower rate of speech. These properties, especially the pitch contour cues, have been shown to govern infants' demonstrated listening preference for motherese [30].

Previous studies suggest that infants learn certain prosodic regularities characteristic of their native language at an early age. These properties include the intonation patterns, stress patterns, and rhythmical structure characteristic of a particular language. Studies suggest, for example, that newborns prefer to listen to utterances in their mothers' native language rather than utterances in a foreign language [31], and that they recognize their mother's voice at birth [32]. This may be due to the transmission of certain auditory frequencies, primarily those conveying prosodic information, to the fetus during the last trimester [33].

Recent work by Jusczyk and his colleagues has begun to trace the postnatal development of infants' recognition of the prosodic patterns and the phonotactic rules that typify the infants' native language [34]. Regarding the acquisition of phonotactic rules, the work suggests that at 6 months of age infants fail to prefer English over Dutch phonetic sequences, but that by 9 months of age, infants prefer the sequences typical of their own native language.

Work in our laboratory is currently focused on the nature of phonetic input to the child. The goal is to describe the vowels contained in motherese. In a Masters' thesis study being done by Kathryn Gustafson in Seattle, we have recorded mothers speaking to their infants and to other adults using words that contain the vowel /i/, such as "bead," "keys," and sheep." Mothers used these words a number of times in speech directed to their infants and to another adult. Adults judged the category goodness of each word using our 7-point rating scale. The results indicate that motherese vowels are better instances of the /i/ vowel category than adult-directed vowels. We also observed that the vowels used in infant-directed speech are much longer than those contained in adult-directed speech. When mothers speak to infants they speak more slowly, and slow speech is often clearer, as shown by Lindblom [35].

Jusczyk's work showing learning at the prosodic level and our work demonstrating learning at the phonetic level indicate that infants possess a capacity to learn certain regularities of a language by simply listening to the ambient language input. Both findings suggest a powerful perceptual representational system that is in place prior to the time that infants begin to produce speech [36, 37].

What is given by nature and gained by experience?

The magnet effect raises questions about what is innate and what is learned in speech perception. There is a great deal of evidence showing that the human infant enters the world with an innate ability to discriminate among the phonetic units used in the world's languages [38, 39]. In tests of categorical perception, infants have shown that they are sensitive to the acoustic cues that underlie phonetic distinctions in language. That is, young infants discriminate phonetic units that straddle the boundaries between two phonetic categories, while failing to discriminate phonetic units that fall within a single phonetic category. Infants show this effect even when tested on sounds from a foreign language, ones they have never before heard. In other words, this ability in infants is present in the absence of auditory experience with the specific sounds.

It is theoretically important to note, however, that categorical perception is also displayed by nonhuman animals [10]. I have elsewhere argued that the tendency to partition sounds into gross categories on the basis of certain acoustic features is one that is deeply embedded in our phylogenetic history, and one that played a role in the selection of candidates for a phonetic inventory [40]. The theory I am developing here claims that infants' ability to hear the relevant differences between phonetic units is innate and attributable to general auditory perceptual abilities. Boundary effects are not due to special processing mechanisms that evolved for language in human beings, as has been argued by the Motor Theory [41].

What is thus "given by nature" is the ability to partition the sound stream into gross categories separated by natural psychophysical boundaries, as schematically illustrated in Figure 5.

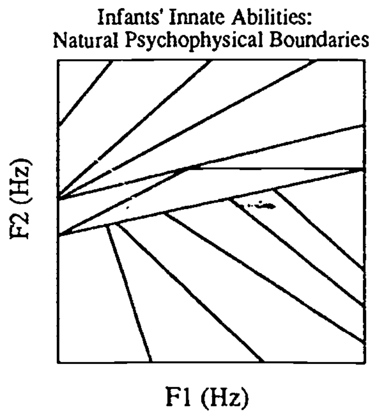

Figure 5. At birth infants perceptually partition the acoustic space underlying phonetic distinctions in a universal way.

Given that the acoustic space is initially divided by natural psychophysical boundaries, boundaries that are also shared by certain nonhuman animals, what is acquired in human ontogeny? Based on the data gathered in the perceptual magnet studies reported here, we can now say that by 6 months of age, infants have something more than the basic cuts they were born with. They now show evidence of language-specific magnets. This is illustrated in the plots shown in Figure 6. Here I schematically portray the acquired magnets in vowel space of infants growing up in Sweden, America, and Japan. The graphs are not meant to be precise with regard to the locations of vowel magnets. They simply convey in conceptual terms the idea that linguistic experience in the three different cultures has resulted in magnets that differ in number and location for infants growing up listening to the three different languages.

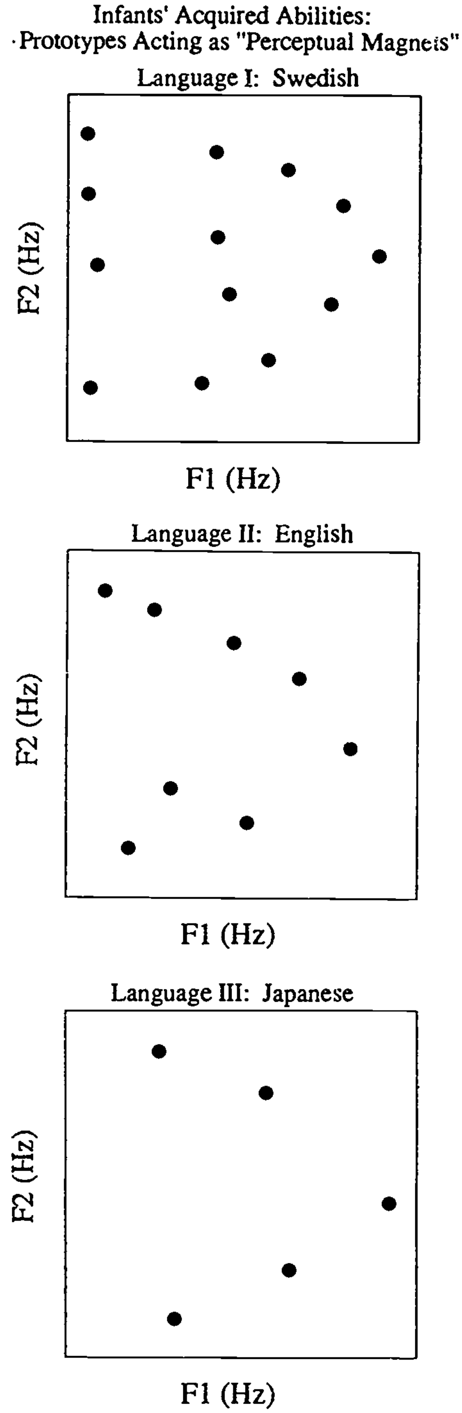

Figure 6. By 6 months of age, infants reared in different linguistic environments show an effect of language experience. They have acquired language-specific magnets that reflect the ambient language input.

If the theory is correct, magnet acquisition subsequently alters the phonetic boundary effect observed in studies of categorical perception. Perceptual magnets will warp the acoustic space underlying phonetic distinctions by decreasing the perceived distance between a magnet and its

surrounding stimuli. This will cause certain perceptual distinctions to be maximized (those near the boundaries between two magnets) while others are minimized (those near the magnets themselves). The effects of magnet acquisition on the boundaries that divide the underlying phonetic space is shown in the schematic diagrams of Figure 7. In essence, the effect of magnets is to cause certain boundaries to disappear. By this account the phonetic boundary effects evidenced at birth in the absence of experience are subsequently altered by linguistic experience.

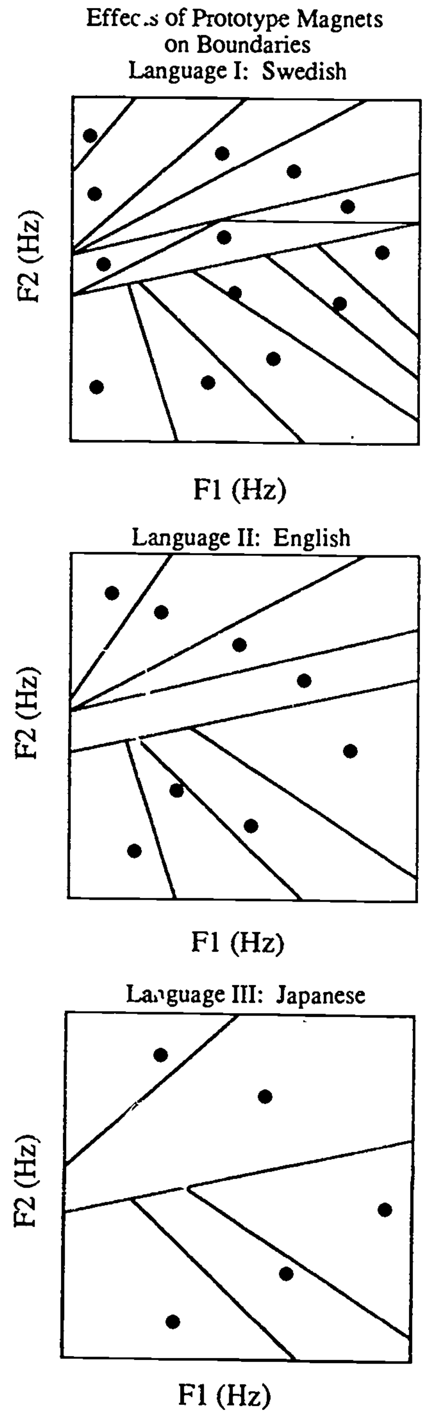

Figure 7. Language-specific magnets cause certain phonetic boundaries to disappear for each group of infants.

We cannot as yet specify the state of the initial mechanism with regard to the magnet effect. That is, we do not know whether magnet effects are present at birth for at [illegible]ne vowels or whether the magnet effect is simply absent at birth, and develops with exposure to a particular language. We are at present testing infants who are only 3 weeks old with the American English /i/ prototype, the American English /i/ nonprototype, and the Swedish /y/ prototype vowels. These studies will prove important in defining the initial state of the speech processing mechanism. It should reveal whether or not infants initially show a magnet effect for all prototypes in the absence of language experience, or whether magnet effects are initially absent and develop with language experience.

Regardless of the outcome of this experiment, we have shown that the effects of language experience occur at an astonishingly early age. Linguistic experience has an effect prior to the time that infants utter or understand their first words. Infants' abilities to learn by simply listening to the ambient language suggests a powerful linguistic representational system that responds automatically given proper input. Nature's initial structuring in the form of natural boundaries, combined with the role experience plays in defining the centers of phonetic categories, provides infants with a strong start on the language acquisition process. The process of acquiring a language-specifc phonology commences in the first half-year of life with the formation of language-specific magnets that define the centers of phonetic categories.

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